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ABSTRACT

Soviet neuropsychologist Sokolov's notions of tonic and phasic orienting responses and of defense responses are examined for relevance to individual information processing. The phasic orienting response provides an index to attention and to information demands generated by the cerebral cortex. The sum of orienting responses elicted by a message would then become the information-demand value of the message. The tonic orienting response appears to be an equivalent to individual capacity to attend at any moment. The defense response is a potential indicator of information processing overload. (Author/AA)

A Physiological Approach to the Study of Human Information Processing

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A Physiological Approach to the Study of Human Information Processing

In Perception and the Conditioned Reflex, Soviet neuropsychologist E. N. Sokolov (1963) described three reflexive responses which the individual nervous system makes to sensory information--the orienting, adaptive and defense responses. A review of these responses and the studies related to them provides additional insight into the nature of human information processing.

Adaptive responses

The adaptive response, or reflex, is described as a local protective mechanism which triggers a specific local response to a specific change in the stimulus environment. An example would be the reflex which closes the pupil of the eye as scene illumination increases. Since adaptive reflexes involve relatively fixed relationships between local stimuli and subcortical responses, they hold little interest for the student of information processing and will not be considered further here.

Orienting responses

The notion of the orienting response has stimulated as much research and writing in psychophysiology as any other idea in the past several decades. Sokolov (1963, p. 11) defined the orienting response (OR) as a nonspecific reaction which better prepares ("tunes") a sensory analyzer to perceive a new stimulus.

Physiologically, the process is something like this. When the sensory apparatus generates neural information about a new stimulus in the immediate environment, neural messages arrive at the cerebral cortex. There the information is compared with stored recollections, or neuronal models (Sokolov, 1963, pp. 282-294), of earlier neural information. If there is a match between the incoming sensory information and the cerebral neuronal models, then an inhibition signal is sent from the cerebrum to the reticular activation system (RAS) of the midbrain. The RAS, in turn, reduces the sensitivity of the sensory apparatus to the stimulus involved.

If, on the other hand, there is in the cortex a mismatch between incoming sensory information and the cerebral neuronal models, an activation signal goes to the RAS which in turn, "tunes," or sensitizes, the sensory apparatus. As a consequence, a greater volume of sensory information about the new stimulus will enter the cerebrum. This activation signal from the RAS to the sensory system is the orienting response (OR) and is measurable physiologically.

As a result of the greater volume of sensory information entering the cerebrum after the OR, a new neuronal model will be formed in the cerebrum. When it is formed, then a match between incoming neural information and the new neuronal model will occur, an inhibition signal will go to the RAS, and the OR will disappear. This reduction of the OR to a new stimulus after a neuronal model has been formed, is called habituation.

The neuronal models formed in this mismatch-OR-habituation process must occur often enough to reflect all the variety of experience with which an individual must deal, including physical characteristics of stimuli, words, syntax, meaning and attitudes. This process is summarized in the graphic model at Figure 1.

Insert Figure 1 about here

The specific physiological measurements related to the OR have been listed by Maltzman and Raskin (1965, p. 1) as "depression of cortical alpha rhythm, the galvanic skin response, pupillary dilation, and a complex vasomotor response consisting of cephalic vasodilation and peripheral vasoconstriction." The reasoning of a number of workers including Lynn (1966), Berlyne (1960), Maltzman and Raskin (1965) and Fletcher (1971) connect the OR to the consciousness-centered concept of attention. Attention has been said to facilitate response and memory (James, 1890, pp. 424-425) and to be a prelude to effective communication (Hovland, Lumsdaine and Sheffield, 1949, p. 81).

In terms of information processing, the OR may be viewed as the process by which external stimulation becomes internalized, and neuronal models may be equated with cognitions.

The OR and entropy

One inference possible from the neuronal model explanation of the OR is that the set of neuronal models in the cerebral cortex has some finite probability of matching incoming neural information from a given stimulus environment. The values of these neuronal models, together with the associated probabilities that the models will inhibit the OR may be taken to represent the negentropy (Kim, 1975, p. 213) of the individual in that stimulus environment, since, if the models match all of the incoming neural information, no new models need be formed, and the pattern of stored cerebral experience satisfactorily accounts for, or organizes the stimulus. Of course, to establish a numerical value for each of these thousands of neuronal models and their associated probabilities of relevance to even a narrowly defined stimulus setting would be extremely difficult if not impossible.

But, since the OR is elicited whenever the cerebrum does not have models adequately conforming to incoming sensory information, the OR can be viewed as the complement of cerebral negentropy: the relative probability that the OR will be elicited and the sum of probabilities that available neuronal models will inhibit the OR must sum to one.

The OR as attention

The probability that the OR will be elicited is thus entropy, and attention so defined is the human response to the perceived uncertainty in a stimulus environment.

When studying the likely effects of potential alternative messages, the probability that some elements of a message will elicit the OR is equivalent to the probability that the cerebrum will process the neural information that the OR will generate. If the messages are persuasive in objective, then those parts of the message which require attention (elicit ORs) should be those that are important to the persuasive intent. If other than important parts of the message elicit the OR, those parts of the message may be said to be distracting attention. If, on the other hand, only those parts of the message which are important to the persuasive objective elicit the OR, then the message can be said to be without distractions.

The OR as information demand

It is the state of the cerebrum with its neuronal models that establishes the sensitivity of the sensory apparatus. Greater sensitivity follows the OR. The OR may then also be taken as an index of cerebral information demand. The average amplitude of the OR elicited by a message would then become the information demand value of that message.

The information demand values of possible alternative messages in mass media campaigns, in instructional materials and in man/computer interaction could be valuable design considerations and argue for the greater physiological study of such messages.

Tonic versus phasic OR

At this point it is necessary to distinguish between two different kinds of orienting responses--phasic and tonic (Lynn, 1966, p. 4). The ORs described above and related to attention and information demand are the phasic ORs; they are relatively close, time-wise, to the sensory information that triggers them and have a relatively short duration.

Tonic ORs are also sudden in their appearance and have relatively long duration.

The distinction between tonic and phasic ORs will be clearer when a specific physiological system--the electrodermal system--is considered.

Insert Figure 2 about here

Electrodermal activity represents changes in the permeability of the skin to the potassium ion (Christie and Venables, 1971), the permeability increasing as the skin is sent ORs by the RAS. In Figure 2 the upper trace represents a typical isolated skin conductance response. Electrodermal activity is measured either by electronically measuring the changes in conductance of the skin, or the changes in electric potential of the skin. The skin conductance response begins 1/2 to one second after stimulus onset and recovers in about 1/2 to 2 1/2 seconds.

The lower trace in Figure 2 represents a tonic OR. It builds at about the same rate as the phasic OR but lasts much longer, perhaps as much as fifty minutes and more. In studies employing standard physiological recording techniques, tonic and phasic responses are separated for analytic purposes.

Generally speaking, the greater the tonic ORs triggered in an individual the more frequently phasic ORs will be triggered in response to the same stimulus. At the same time the law of initial values (Wilder, 1957 Sternbach, 1966) will affect this relationship of phasic and tonic ORs. The law of initial values states that the size of a response to a stimulus will be a function of the prestimulus level of the response system. As phasic ORs occur with or on top of larger tonic ORs, the phasic ORs will be more frequent but smaller.

Tonic OR as capacity to attend

The tonic OR may be viewed as setting the cerebral capacity to attend to sensory information demands. As tonic OR increases, the frequency of information demand (phasic OR) will increase, but the amplitude of information demands will decrease. As individual capacity to process information increases, demands for information should increase in frequency, but the amount of information (size of the phasic OR) required to develop a neuronal model should be less.

As a corollary, the communication setting in which a message occurs will be very important in establishing the information demand values of the message. Illustrative is a study by Kennedy (1971) in which the effectiveness of television commercials was shown to be influenced by the television program setting in which they were shown.

Conversely, the sum of the information demand values of all the separate messages in a communication setting will be related to the likelihood and amplitude of the tonic ORs. This principle has some importance to the study of relaxation, where the phenomena in question deal with information processing patterns which seem to reduce the information demands associated with the communication setting.

In the case of public response to popular music, for example, what is it about such music that accounts for the common assertion by devotees that familiar music is relaxing? Familiar music has low information demand values, since neuronal models of its characteristics had to be established before it could become familiar, and relatively small phasic ORs are elicited by music that is familiar. In any communication setting where such music is present, the sum of the information demand values of all of the messages in that setting, will decline when familiar music becomes part of the setting. Hence tonic ORs should decline in a setting identified by familiar music. This result does indeed occur, as recently reported in a study of popular radio music (Fletcher, 1976).

The same principle is manifest in intra-family communication. Goldstein et al (1970) found that families containing disturbed adolescents exhibited high levels of tonic OR when discussing the problems of the adolescent. High tonic OR would mean reduced but more frequent phasic ORs. Hence more of what is said demands information, although the strength of these demands is lessened. The result of these opposed trends is low effectiveness in the capacity of family communication to deal with these adolescent problems.

The defense response

Lynn (1966, pp. 8-10) identifies the defense response (DR) with the startle reaction described in American and European literature. The specific physiological indicators of the DR include momentary but marked increase in heart rate and blood pressure, and positive going skin potential (Raskin, Kotses and Bever, 1966). The positive going skin potential is the simplest of these to record and is shown in Figure 3.

Insert Figure 3 about here

Shnidman (1966) demonstrated that subjects in an avoidance conditioning group experienced greater DRs.

What are the consequences of the DR upon information processing? Generally speaking, retention of a message is lower when the message elicits the DR (Thetford, Klemme and Spohn, 1968; Wilcott, 1958). The DR appears to correspond to inefficiency in cerebral information processing. As DR increases, the cerebral cortex demands more information but produces fewer neuronal models from the information. The DR is usually accompanied by an increased number of phasic ORs, so that an increase in information volume occurs in the cortex at the same time as this reduced efficiency. The resulting state of affairs may be a good description of information processing overload. And, due to its relative sensitivity, the DR may provide an index to otherwise undetectable levels of information processing overload.

Summary

The principal potential contributions of physiological constructs--the phasic OR, the tonic OR and the DR--to an understanding of individual information processing may be summarized in the following propositions.

1. For any neural signal corresponding to a given message there is some probability that the central nervous system will generate a generalized demand (phasic OR) for additional neural information.

2. The capacity to respond to neural signals by demanding additional information (tonic OR) is a function of the total information demand value of the communication environment.

3. The information demand value of a communication (its ability to elicit phasic ORs) declines as neuronal models (cognitions) are formed.

4. As the messages in a communication context continue to generate information demands (phasic ORs), the capacity of the individual respondent to attend (tonic OR), all else being equal, must decline.

5. Communication settings in which information demand values exceed capacity to attend (tonic OR), cerebral processing of information into neuronal models must become less efficient (DR).

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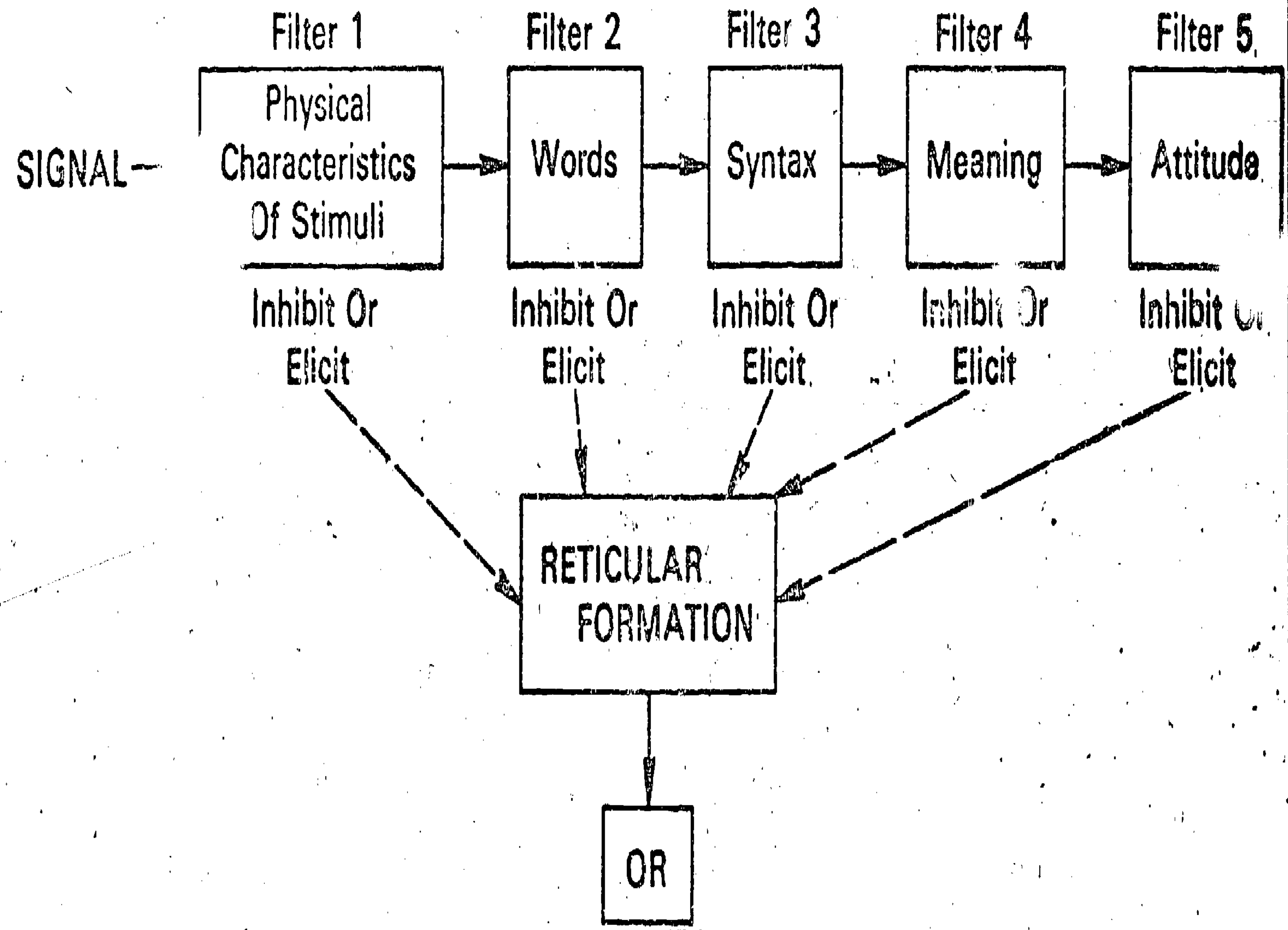
Figure Caption

Figure 1. A graphic model of the elicitation of an OR.


Filter 1
Filter 2
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SIGNAL
Physical Characteristics Of Stimuli
Words
Syntax
Meaning
Attitude
Inhibit Or Elicit
Inhibit Or Elicit
Inhibit Or Elicit
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Elicit
RETICULAR FORMATION
OR

Figure Caption

Figure 2. Typical isolated phasic and tonic ORs as reflected in skin conductance measurement.

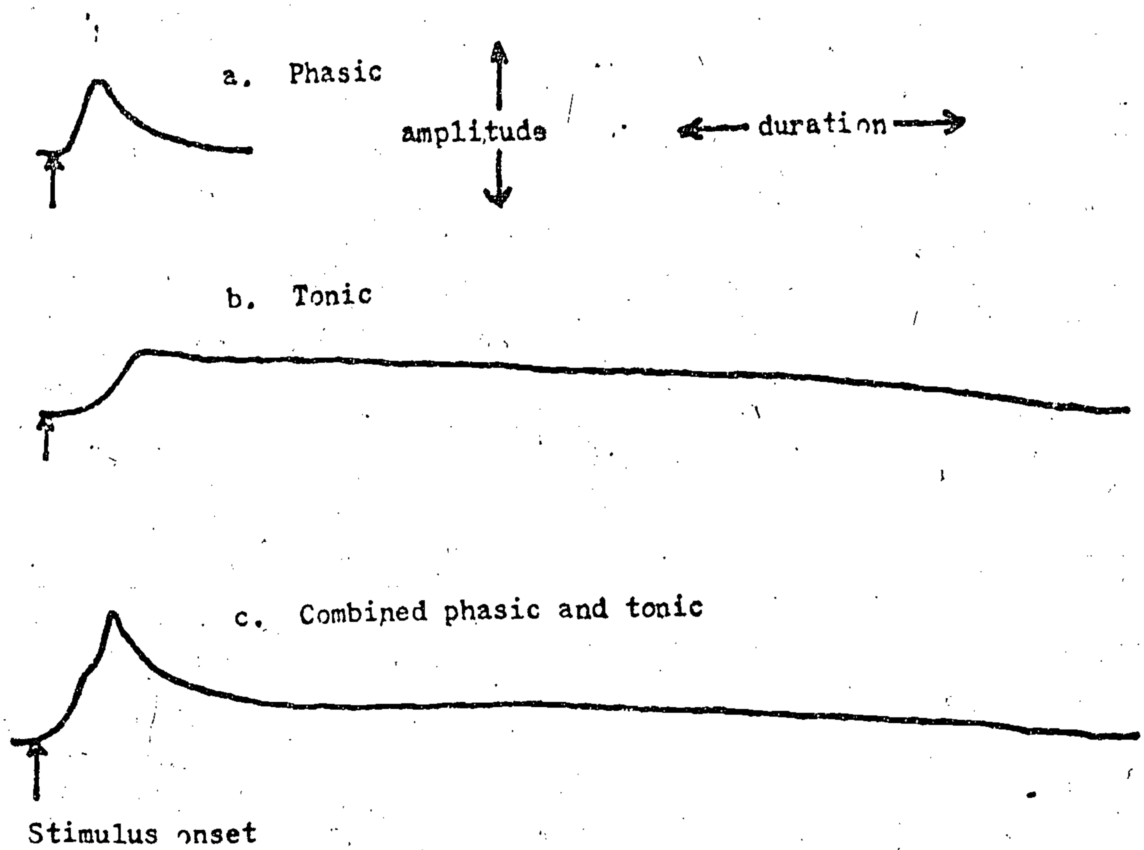
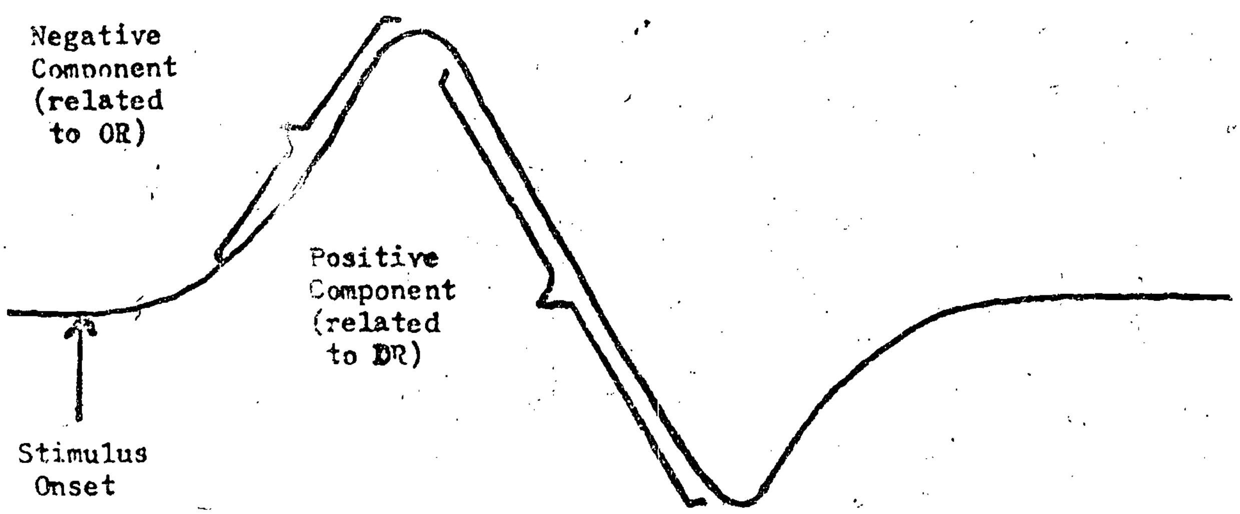

a. Phasic
amplitude
duration
b. Tonic
c. Combined phasic and tonic
Stimulus onset

Figure Caption

Figure 3. Typical isolated skin potential response labelled to show negative component related to OR and positive component related to DR.


Negative
Component
(related
to OR)
Positive
Component
(related
to DR)
Stimulus
Onset